Nesting Behavior of *Cheyletus eruditus*

(Acarina: Cheyletidae)

F. M. SUMMERS AND R. L. WITT

University of California, Davis, 95616

The nesting behavior of some species of *Cheyletus* is possibly one of the key factors that severely restricts the period within which mating may occur. Mating is most apt to occur very soon after *Cheyletus* females complete their final moult. The acceptance of males by older, unmated, gravid females appears to be unusual. Evidence from laboratory cultures of one species, *C. malaccensis* Oudemans, suggests that there may be limited times or special conditions when older virginal females will mate. In a preliminary study of mating and oviposition in *C. malaccensis*, we postulated that the mating of older virginal females may be prevented by their belligerence after a nest is made (Summers *et al.*, 1972).

Local strains of *C. malaccensis* have both sexes and the females are facultatively parthenogenetic and arrhenotokous. Brooding females of this and other *Cheyletus* species reared in our laboratory exhibit marked ferocity when their nests are disturbed. The place in which eggs are laid is called a "nest" and it is here that the female exhibits an aggressive kind of behavior, which may be interpreted as defense of territory or protection of eggs. This kind of overt behavior has not been detected before the nest is established.

Cheyletus eruditus (Schrank) was selected for this initial study because the race being reared has no males and parthenogenesis is thelytokous. It is thus possible to observe nesting and oviposition apart from mating and other complications which the presence of males may introduce. This species is also quite prolific. Our estimates of productivity by *C. eruditus* fed on *Acarus siro* Linnaeus greatly exceed the values recorded by Beer and Dailey (1956) for *C. eruditus* fed on *Tyrophagus* sp.

There were three reasons for setting up this study. The nesting activities of these predaceous mites are intrinsically interesting. We hope to pursue further research on the interrelations of mating and nesting within several of the species which normally have males and the information developed in this study may be basic. A third reason is that our long practice in the handling of isolation cultures of *Cheyletus* assures that case histories of individual mites can be followed to completion with expectations of a low incidence of mortality by accident.

THE PAN-PACIFIC ENTOMOLOGIST 48: 261–269. OCTOBER 1972

METHODS

Active or moulting deutonymphs of the predator were sealed into isolation cells containing a moderate number of prey mites and five to seven flakes of wheat bran. The flakes were selected so as to provide nesting sites acceptable to the mite and convenient for an observer to manipulate. These were usually polygonal in outline, rigid, somewhat dark in color, without complicated curls or folds, and cupped on the rough (endosperm) side.

The isolation cells ultimately developed (Fig. 1) proved to be very serviceable. Each cell comprised a 10 mm length of thick-walled glass tube sealed at one end (bottom) with brown cigarette paper and closed at the other end (top) with thin sheet plastic (Saranwrap®). The cells were sawed from a glass tube approximately 32 mm O.D. and 24 mm I.D. The cigarette paper was permanently affixed with warm, dilute gelatin and the surplus paper margins later burned away. The circular Saranwrap closures were cut with scissors from a paper sandwich, plastic placed between sheets of rough paper. The top closures were fastened was a very thin film of vaseline. They could be peeled off and resealed several times before replacements were required. The tissue paper bottom was freely permeable to water vapor. Each cell was provided with a square plastic base or holder, 50 × 50 × 6 mm, drilled with a 24 mm center hole and a 36 mm countersunk shoulder. The holders made the handling of the cells much easier. The cells containing mites were stored at room temperature in a moist chamber having a wire grid shelf suspended over saturated aqueous KCl (80–85% R.H.). This fairly high humidity was possibly more vital for *Acarus siro* (Solomon, 1962; Knülle, 1965) than for the predators.

Stocks of the prey mite, *A. siro*, were stored under similar conditions. The acarids were cultured in glass tubes 60 mm long, 18 mm O.D., which were sealed on one end with cigarette paper and with a snap-cap on the other. These mites grew very well when they were fed on wheat bran plus quick-cooking oats, about 20:1 by volume. The transfer of prey mites to isolation cells was accomplished easily with the aid of the snap-caps. A cap removed from a thriving acarid culture was inverted over an open culture cell and lightly tapped with a pencil. The striking force was adjusted to sprinkle food mites in small quantities, about 25 to 100 mites. In this manner there was no carry-over of additional bran or crude debris.

The unsupported paper bottoms of these isolation cells are resilient, like the membrane of a drum so that slips of manipulating tools sometimes catapulted both bran flakes and mites out of the cells. Two non-

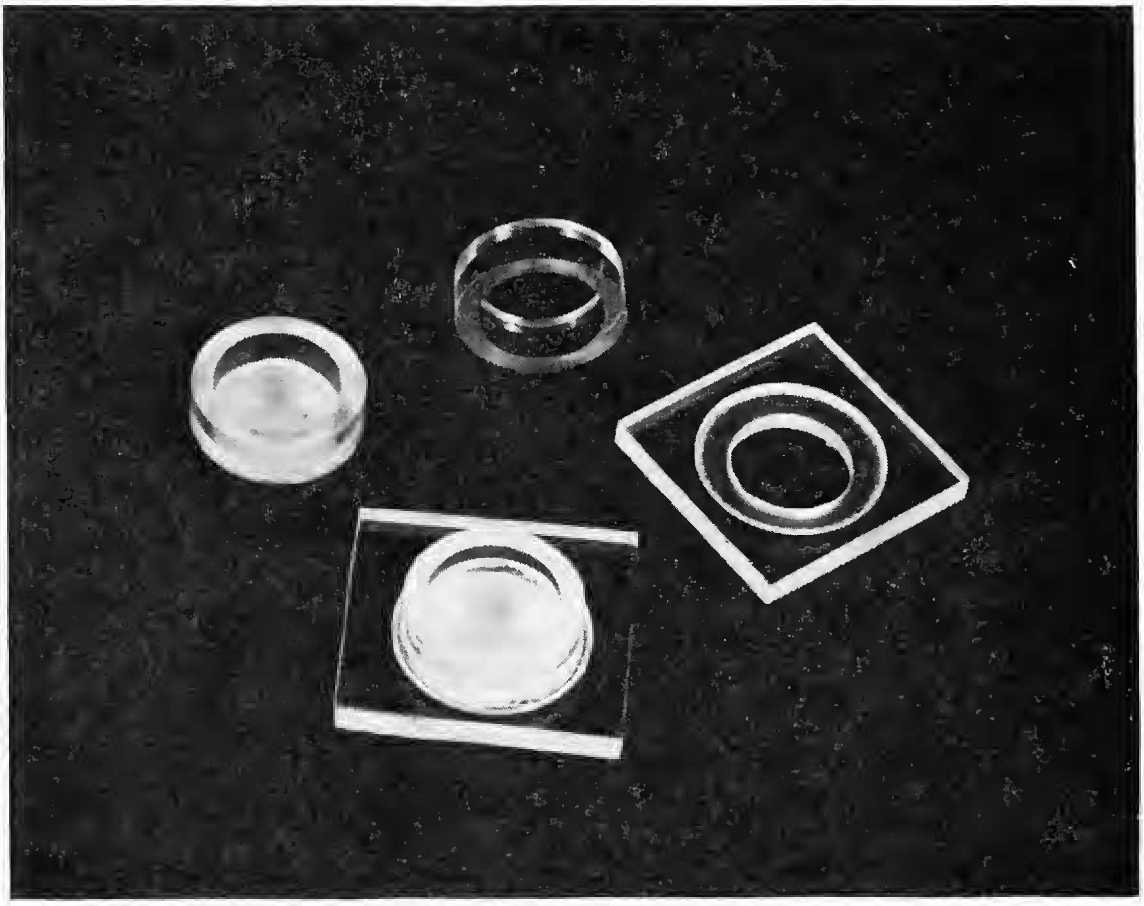

FIG. 1. Components of the culture cells. The one in the lower center is assembled but has no plastic film cover.

flexible tools were generally used: a fine-pointed jeweler's forceps and a rigid-shafted needle having a lancet tip. When a nest was operated upon to remove eggs, shells or dead prey, the cell was lifted from its plastic supporting base and placed directly on the glass stage of a microscope. Closed forceps were used to press the bran flake (nest) against the glass-supported paper bottom while the needle was used as a scoop or pick. Active progeny of the cheyletids were routinely destroyed.

These cells were especially useful for the rearing of *Cheyletus* because the species cultured are cryptic and rarely climb far up the walls of the cells.

OBSERVATIONS

Individuals of *C. eruditus* are negatively phototaxic and positively thigmotaxic within limits not precisely determined since the physical conditions provided were fairly constant. Mites of this species developed vigorous colonies in glass culture tubes partly filled with bran and acarids, and they established nests (Fig. 2) under bran flakes dispersed on the paper bottoms of the isolation cells.

The nesting sites provided were concave flakes of bran having slight

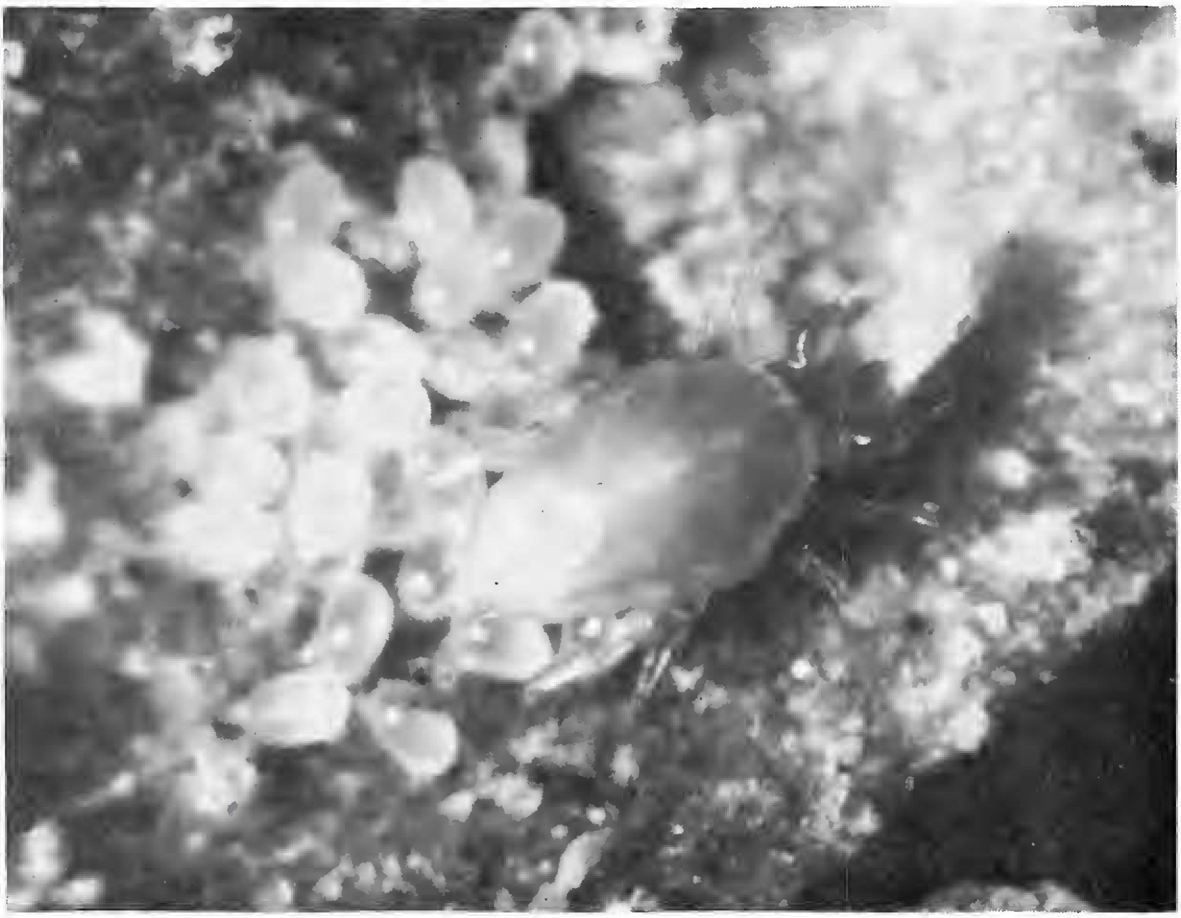

FIG. 2. A prime nest of *Cheyletus eruditus* on the rough surface of a bran flake. Females most frequently stand upon or over the egg mass. The highly reflective spot within the opisthosoma of this female is an accumulation of crystals within the so-called excretory organ (proctodeum).

twists or projections to prop them slightly above the bottoms of the cells. Appreciably elevated pieces were rarely selected by the mites for nesting sites if other options were available. The homesites most often occupied were those in which the vertical dimensions of the free space were not much greater than the thickness of the mites' bodies. Individuals entering nests were not deterred by limited clearance at the access point: they merely lifted the margins by pushing under. Nesting mites most frequently reposed upside down, clinging to the ceiling of the domicile. They either crawled under in the upright position and then inverted themselves, or they crawled in an upright position to the edge of a chip and inverted as they turned under, as though moving from roof to ceiling. Body orientation appeared not to be a critical factor in site selection. The cheyletids were observed to perch in all positions with respect to the gravity axis, usually with their bodies lightly wedged into a restricted space. Movements of the mites on nests beneath bran flakes were often revealed when the flakes themselves appeared to creep.

Two actions were clearly displayed by nesting females. One was combativeness. A nesting or brooding mother quickly attacked an intruding probe. This overt act involved forward body thrust and strong clamping motion of the pincer-like pedipalps. Another aspect of the nesting behavior was the marked tendency of the mother to remain within the nest, on or very close to her clutch of eggs. The counting of eggs by an observer often required that the female be pushed off the pile of eggs. Whenever mothers were completely dispossessed and the homesites removed, they tended to hover and probe as though trying to return.

The actions of the predators appeared to vary when prey mites entered their nests. If food mites were continuously abundant, the predators either tolerated their presence or confronted and turned them away. Less often the predaceous species retreated and avoided the intruders. Of course, at other times, the prey mites were speedily grasped and fed upon. Nests were frequently cluttered with dry or empty bodies of acarids. Partly devoured bodies adhered to the nest or to the eggs therein. The food remnants were sticky and often adhered for a time to various parts of any of the living mites. It is believed that food mites whose body fluids were partly consumed at one feeding were used again. It has been noted that a nesting mother may carry or push food remnants out of the nest. These housecleaning acts were possibly a consequence of efforts of the occupant to feed upon too-dry food remnants.

The deposition of eggs has never been witnessed during the course of many hours of attention to cultures. The eggs were deposited in clusters or piles and on the smooth (integument) or rough (endosperm) surfaces of bran flakes, on paper or on glass. Older, prime nests contained a single mass or pile of embryonated eggs and empty shells. Commonplace also were a few collapsed eggs fed upon by the mother or her neonatal daughters.

The eggs are not fastened to the substrate with copious amounts of adhesive secretion. Their surfaces are tacky, however, and the eggs remain fairly secure when hanging from above or as placed on vertical walls. When they are scooped out of nests with a pick, they readily come away from the surface and it then becomes apparent that they are loosely bound together with strands of silk. The silk or silk-like strands are otherwise rarely noticed.

In a preliminary study of reproductive capability and nest occupancy, 18 moulting deutonymphs were placed in separate cells and reared according to the four regimes listed in Table 1. In this trial, the cells were opened and inspected once daily except Saturdays and Sundays. The eggs were counted individually when possible, otherwise the number was

TABLE 1. Summary of 18 case histories, four regimes of treatment.

		Vital activities (averages)		
Regimes	No. of observa-tions	Life span (days)	Total eggs per female (est.)	Number of nests made
R1. Normal-minimum disturbance	4	56.8	129.0	5.3
R2. Dispossessed	4	47.8	107.8	8.0
R3. Starved continuously	7	52.6	32.9	2.0
R4. Starved first 46 days	3	77.3	110.7	5.7

estimated. Whenever the mites maintained under the dispossessed regime (R2) formed nests, they were dislodged at the time of the inspection and the nests moved to new locations within the cells. The eggs within these nests were not otherwise molested. The data secured in this experiment indicate that the periodically dispossessed females (R2) lived shorter lives, laid fewer eggs and made more new nests than less disturbed females (R1). However, the frequency with which displaced females returned to their original nests was greater than anticipated. There is possibly no individual specificity among nests because we were able to interchange nests and mothers with 100 per cent success ($n = 6$) and without obvious disruption of the laying functions.

Ten individuals isolated as moulting deutonymphs were maintained thereafter without food for most or all of their adult lives. Each starved female deposited a few eggs during the first 15 days of adulthood and then entered upon a nomadic period during which no nests were established and incidents of cannibalism were commonplace. The continuously starved individuals (R3) did not perish prematurely but their nesting capabilities were severely curtailed.

Three of the starved individuals (R4) were presented with food on and after the 47th day. The starved mites had become pale, flat and somewhat angular in outline. After three days with ample food they plumped up and resumed laying. In respect to nesting behavior and egg productivity, the later fed females were not clearly distinguishable from continuously fed females but their lives appeared to have been prolonged by the initial fasting period. The presentation of prey to the starved predators evoked reactions not very obvious among amply fed individuals. When about 50 acarids were sprinkled into the cells for the first time, the hitherto listless predators quickly became excited or alert to the proximity of food. Their groping gyrations and other overt motor functions were intensified considerably before the first physical contacts occurred. Starved individuals displayed no arousal from lethargy when human breath was gently pipetted into their cells. But a burst of searching activity was triggered very soon after the paper bottoms of isolation cells were placed over the open ends of vials containing cultures of acarid mites.

The foregoing experiment showed that nesting females must feed and are able to leave their nests to forage and then return, and that prolonged starvation induces a state of restlessness or wandering. The estimates of egg production and the data on duration of nest occupancy are fairly crude, however, and the natural causes of nest abandonment were not apparent.

A more refined experiment was then set up to pinpoint, if possible, the duration and rhythms of oviposition and nest occupancy. In this trial, 50 individuals were maintained under three regimes of manipulation and with examinations once every day. All were amply fed on *Acarus siro* but only the 40 included in R2 and R3 were isolated as deutonymphs. Individuals in regime R1 were inspected regularly but disturbed only to the extent necessary to ascertain that the female was "at home." Individuals of regime R2 were manipulated as little as needed to provide accurate counts of eggs laid. Some eggs and all empties were removed so that, as a rule, about five to ten of the newest eggs were left after each inspection. Individuals in regime R3 were dispossessed and their nests taken out whenever found during inspections. These individuals often scattered their eggs instead of depositing them in clusters.

The second experiment (Table 2) provides somewhat better assurance that less disturbed individuals (R2) lived longer lives and laid more eggs than those whose nests were removed daily (R3). Differences in degree of manipulation did not appear to affect the duration of the laying period.

The numbers of eggs obtained under regime R2 showed that egg production per female, as determined by actual counts, exceeded the average production per female according to estimated numbers of eggs (R1, Table 1). The maximum number of eggs laid on one day was 27 and the highest productivity occurred during the first one-third of the laying period. All active instars of cheyletids show marked cannibalism. Accordingly, these estimates exceed all previously reported values because the active progeny were routinely destroyed and the counts include the collapsed eggs fed upon by the mother or by recently hatched larvae.

The period during which reproducing females exhibited nesting be-

TABLE 2. Summary of 50 case histories, three regimes of treatment.

Regimes	No. of observations		Vital activities: Life span (days)	Laying period (days)	Total eggs per female	Number of nests made
R1. Mild disturbance: determinations of nest occupancy	10	Mean	—	—	—	2.5
		Range	—	—	—	1–4
R2. Moderate disturbance: nests inverted, some eggs removed	19	Mean	61.6*	44.2	169.4*	5.0
		Range	33–83	22–59	70–317	1–12
R3. Severe disturbance: nests removed daily	21	Mean	49.8*	41.1	141.6*	—
		Range	20–76	14–60	77–204	—

* Differences significant at $P = 0.05$ by t test.

havior slightly exceeded the duration of laying. Ten females tested under regime R1 (Table 2) were maintained in isolation cells only for data on nest tenure. They were vigorous, young adults when isolated. These individuals averaged one-half as many nests as the individuals manipulated as described in regime R2. Three of 10 individuals in the R1 lot and two of 19 individuals in the R2 lot never left their original nests, except for brief excursions, until oviposition ended. Among R2 individuals, for which actual egg counts were made, approximately 48 per cent of the eggs were deposited in the first nest and an additional 28 per cent in the second nest. Thereafter the frequency of new nest formation increased while oviposition waned. Females in regime R2 averaged 3.9 days pre-oviposition, 44.2 days of oviposition and 13.0 days in the post-ovipositional, wandering phase.

Three extrinsic factors have been observed to terminate or prevent nesting in laboratory cultures of this species: (1) starvation, (2) overcrowding with prey mites, and (3) the turning-over of the nests—physical disruption of the microcavern, too much light or heat. In these trials, the changing of nests by females in the prime period of oviposition may have been induced artificially by movements unavoidable in the handling of cultures. The intervals between the first few nests were short and not noteworthy. The waning of egg laying correlated with the onset of discontinuity in nesting, and most of the new nests were established during the attenuated portion of the oviposition period. In this male-less race of *C. eruditus*, belligerent nesting behavior seems to persist throughout most of the laying cycle.

LITERATURE CITED

BEER, R. E. AND D. T. DAILEY. 1956. Biological and systematic studies of two species of Cheyletid mites, with a description of a new species (Acarina, Cheyletidae). Univ. Kans. Sci. Bull., 38, part I, (5): 393–437.

KNÜLLE, W. 1965. Die sorption and transpiration des wasserdampfes bei der Mehlmilbe (*Acarus siro* L.). Z. Vergl. Physiol., 49: 586–604.

SOLOMON, M. E. 1962. Ecology of the flour mite, *Acarus siro* L. (= *Tyroglyphus farinae* DeG.). Ann. Appl. Biol., 50: 178–184.

SUMMERS, F., R. WITT AND S. REGEV. 1972. Evaluation of several characters by which five species of *Cheyletus* are distinguished (Acarina: Cheyletidae). Proc. Entomol. Soc. Wash., 72: 230–252.

BOOK REVIEW

THE INSECT REALM. A GUIDE TO THE HALL OF INSECTS. By Charles L. Hogue and Fred S. Truxal. Los Angeles County Museum of Natural History. 99 pages, 106 figs. 1970. $2.00 [paperback].

Designed to complement the displays in the Hall of Insects of the Los Angeles County Museum of Natural History, the book admirably fulfills its goal. Although expressly not intended as a textbook in entomology, it could stand on its own merits as an introduction to many fascinating aspects of entomology.

The book is not organized in the same sequence as the displays, but an Appendix with map servcs as a cross-reference. The book begins with considerations of the systematic relationships of insects to other animals and the geologic history of insects; then to discussions of structure and function, growth and development; followed by extensive considerations of insects in relation to their environment and insects in relation to man as medical, agricultural and house and garden pests as well as beneficial insects; to final sections on the orders of insects and how to collect and preserve insects.

The discussions and displays are aimed at the general public, but contain sufficient diversity and information to be of interest to undergraduate entomology majors. The major deficiencies in the book are the discrepancies between the ordinal names and phylogenetic relationships used in the genealogical chart (page 4) and the major groups chart (page 70), and the lack of many of the display illustrations. The latter is undoubtedly intentional, so that one must visit the displays and use the book to provide a record of a memorable tour of "The Insect Realm."—R. W. THORP, *University of California, Davis, 95616.*